XBT AND CTD TEMPATURE MEASUREMENT COMPARISON
AND
XBT AND GDEM SOUND VELOCITY PROFILE COMPARISON

LT Annie Laird
OC3570 Operational Oceanography and Meterorology
R/V Point Sur Cruise
19 January 2006 – 26 January 2006

This study has two aims. The first is to compare the temperature versus depth profiles obtained in this cruise using the XBT against temperature versus depth profiles obtained using the CTD at the same sampling stations. The second is to compare the sound velocity profiles obtained in this cruise using the XBT against sound velocity profiles generated using GDEM data obtained from the Naval Oceanographic Office website. This paper will include a review of data collection methods, results, and a discussion with mention of previous studies and the impact of sound velocity profile errors upon naval operations.

DATA COLLECTION

The CTD-XBT comparison was comprised of thirteen collocated XBT/CTDs of which six were obtained during cruise one and seven during cruise two. The locations of each collocated XBT drop and CTD cast are listed in Appendix A and plotted in Appendix B. In order to enhance clarity and render the data analysis easier, the XBT launches and CTD casts used in the comparison were renumbered 1 through 13 and therefore the numbers do not coincide with the numbers recorded in the laboratory log/cruise report. Most of the data collection locations had a water depth of over 1000 meters, so the entire data set from XBTs could be analyzed. The only exception was site 12, which was shallower; data was only collected to a depth of 745 meters. The Sippican T-7 XBT has an operational depth of 760 meters. The CTD can be lowered to a desired depth and was generally lowered to a depth of 1010 dbar (1000 m); however, depth restrictions at site 12 limited that CTD to a depth of 752 dbar (745 m).

After the cruise ended, the GDEM data was extracted from the NAVO website. The database access mode was 'single point', that is, a single latitude and longitude were

wire of the XBT may have possibly made contact with the ship and caused the spike. Whatever the reason, all of the XBT-8 data below 630 meters was replaced with NaN (not a number) for lack of accurate digitized readings.

Following visual inspection, a MATLAB program was used to compile the data into separate matrixes: a XBT temperature matrix, a CTD temperature matrix, a XBT sound speed matrix, and a GDEM sound speed matrix. MATLAB then compared the data point at each level in one matrix to the average of the data in the levels above and below it in the same matrix. In particular, each data point was compared to the average of the temperatures or sound speeds of the surrounding two levels. If the data point differed by more than two standard deviations from the average of either of the surrounding levels, it was identified as a possible bad data point, and flagged for further investigation. For the top and bottom levels, only one level was available for comparison.

The total number of data points checked was 11022 (4906 XBT temperature + 4973 CTD temperature + 571 XBT sound speed + 572 GDEM sound speed). Of these, 207 CTD (4.16%) and 202 XBT (4.12%) were identified as possibly bad data points. No GDEM data points were identified as possibly bad. All were looked at more closely, and found to be part of a logical sequence decreasing with depth in the case of the temperature data points, or approaching a constant as the depth increased in the case of the sound speed data points. Therefore, all of the data points run through the MATLAB routine were considered reasonable and consistent, and no further data was excluded.

METHODS OF DATA PROCESSING

Due to the high accuracy and calibration of the Sea-Bird CTD, the CTD temperature measurements were considered to be the true representation of the
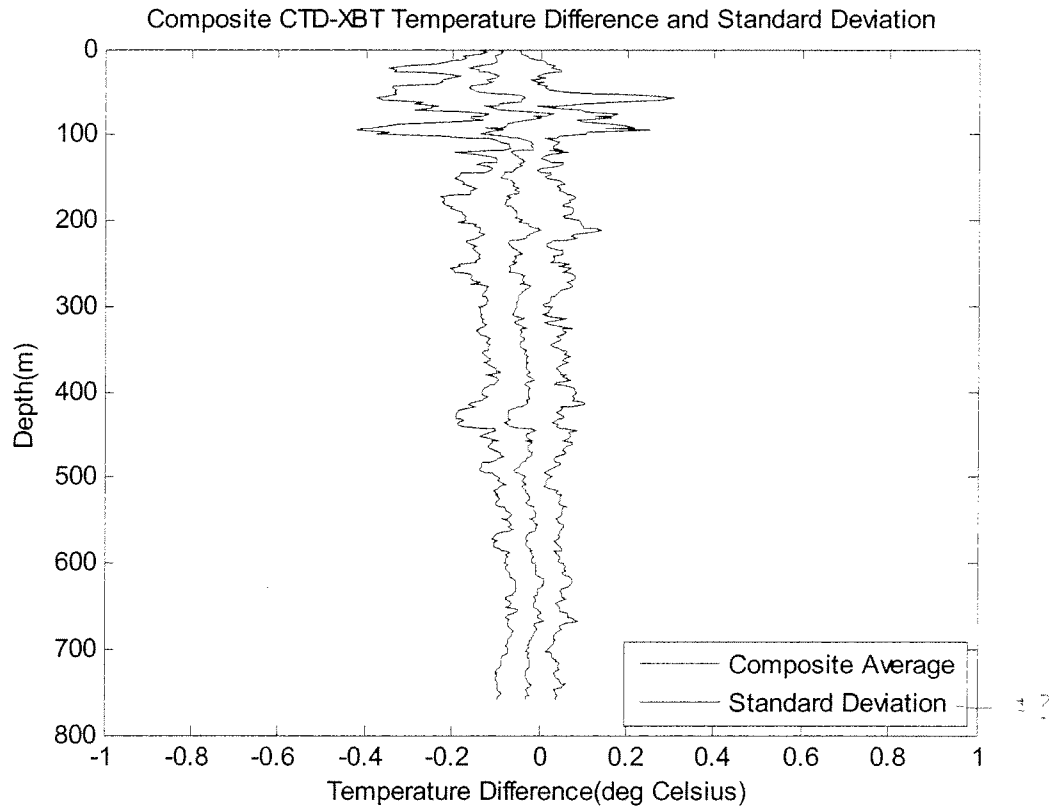
Figure 1. *The mean and standard deviation of temperature differences from the 26 collocated CTD and XBT drops.*

For each XBT/GDEM pair, the XBT sound speed at each depth was subtracted from the GDEM sound speed. Two plots were made for each pair. The first contained the sound speed profile for each sensor (The CTD sound speed profiles were also included in these graphs). The second showed the sound speed difference at each level. These plots are shown in Appendix E. For the 13 sets, sound speed differences were combined, and the mean and standard deviation determined by MATLAB for all levels. These statistics are plotted in Figure 2.

standard deviation of 0.342°C was observed at 57 meters. The standard deviation below 200 meters was 0.08°C and also generally decreased with depth.

It should be noted that many of the large magnitude temperature differences occurred in the upper levels. The large vertical temperature gradients in the upper levels demonstrate that many of the apparent temperature differences are in fact depth differences. Therefore, if the depth difference exists, the stronger temperature gradients result in larger temperature differences.

A similar study was published in 1983 by Heinmiller et al. Heinmiller et al. studies both Sippican T-4 and T-7 XBTs and used a calibrated Neil Brown CTD. The portion of the Heinmiller et al. study comparing the T-7 XBT to the CTD was conducted in the Sargasso Sea and consisted of 139 casts.

Also, five previous OC3570 similar studies of CTD and XBT profiles have been performed by Schmeiser (2000), Roth (2001), Boedeker (2001), Fang (2002), and Dixon (2003). Schmeiser's, Roth's, Boedeker's, Fang's and Dixon's study compared 18, 9, 27, 28, and 24 CTD/XBT pairs respectively. This study performed statistics on 13 pairs. All compared Sippican T-7 XBTs to a Sea-Bird CTD onboard the R/V Point Sur along the central Californian coast.

Schmeiser (2000) provides a detailed comparison of the data collection and editing techniques of the Heinmiller et al. (1983) with his study. Since the techniques of this study are very similar to those of Schmeiser (2000), a detailed comparison of Heinmiller et al. (1983) with this study would be redundant and readers are referred to Schmeiser (2000).

In the second half of the study, the mean and standard deviation of the sound speed difference between the XBTs and the GDEM sites were determined for 44 levels between the surface and 700 meters. The XBT sound speeds ranged from 2.4796 meters per second faster to 1.6535 meters per second slower than corresponding GDEM data and had an average slow bias of 0.7272 meters per second overall. The maximum average speed difference was observed at the surface and generally decreased with depth, meaning the XBT measurements were closer to the GDEM data at greater depths.

The greatest variability of the sound speed differences was observed in the upper 150 meters. The greatest standard deviations occurred in the upper levels; the maximum standard deviation of 2.9826 meters per second was observed at 70 meters. The standard deviation below 150 meters was 0.65 meters per seconds and also generally decreased with depth.

The five OC3570 studies that were previously completed focus solely on an analysis of the implications of a bias in temperature differences and depth differences. None of them examined sound velocity profiles obtained from GDEM to determine the differences between data collected via an XBT as opposed to extracting it from an online database. The next section considers the tactical implications of using an XBT instead of a CTD and using data obtained from GDEM instead of an XBT.

DISCUSSION

The results of the previous five student projects are generally consistent and this study is in agreement with the results of these studies (Table 1). The selected depth categories of 25-125 meters and 175-375 meters were selected first by Schmeiser (2000) and could be considered somewhat arbitrary. Other depth categories may form a better

11

impacted significantly enough to impose an operational degradation upon the USW

problem.

While not posing a problem in an operational use, the consistent warm bias could

negatively impact climate studies. As with all data, biases should be removed before

using it to draw conclusions. Scientists relying on these XBT profiles to look for global

warming without accounting for the bias would see a rise in ocean temperature even if

there was no change, and an even higher rise if there was. A well designed experiment

could determine an inherent bias and a correction that could be applied to XBT data

collected around the world. The sample size in this study, in addition to the temporal and

spatial variation, is not sufficient for such a determination.

When examining the sound velocity difference between the XBT and GDEM data

it is tempting to conclude that the XBT slow bias of 0.7272 meters per second is not

significant enough of a difference to affect the tactical use of SVP utilizing GDEM data.

However, even small differences in the profiles can have a large impact tactically. Take

for example, the data from site #13:
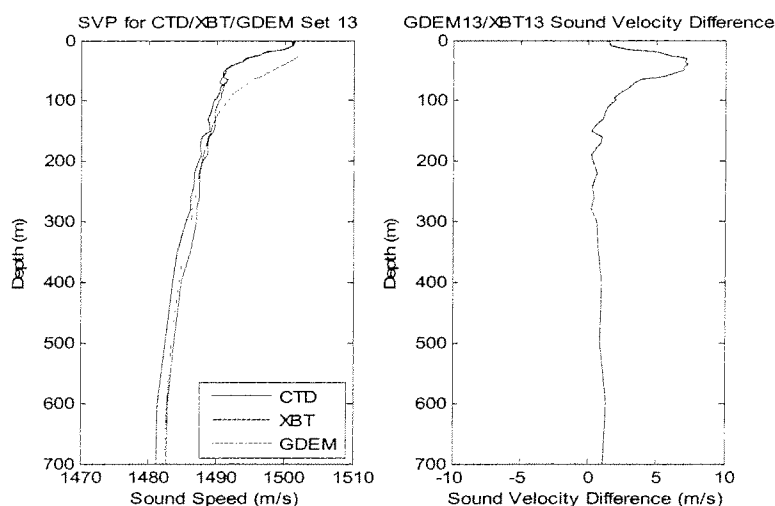
recently fired XBTs to obtain accurate SVPs. Future research should attempt to use a larger sample size of collocated profiles from different locations. As Roth (2001) suggests, the XBT should be released before the CTD to reduce temporal variation. Different batches of XBTs should also be used if possible, since using XBTs with different manufacturing dates will further generalize the results.

APPENDIX A
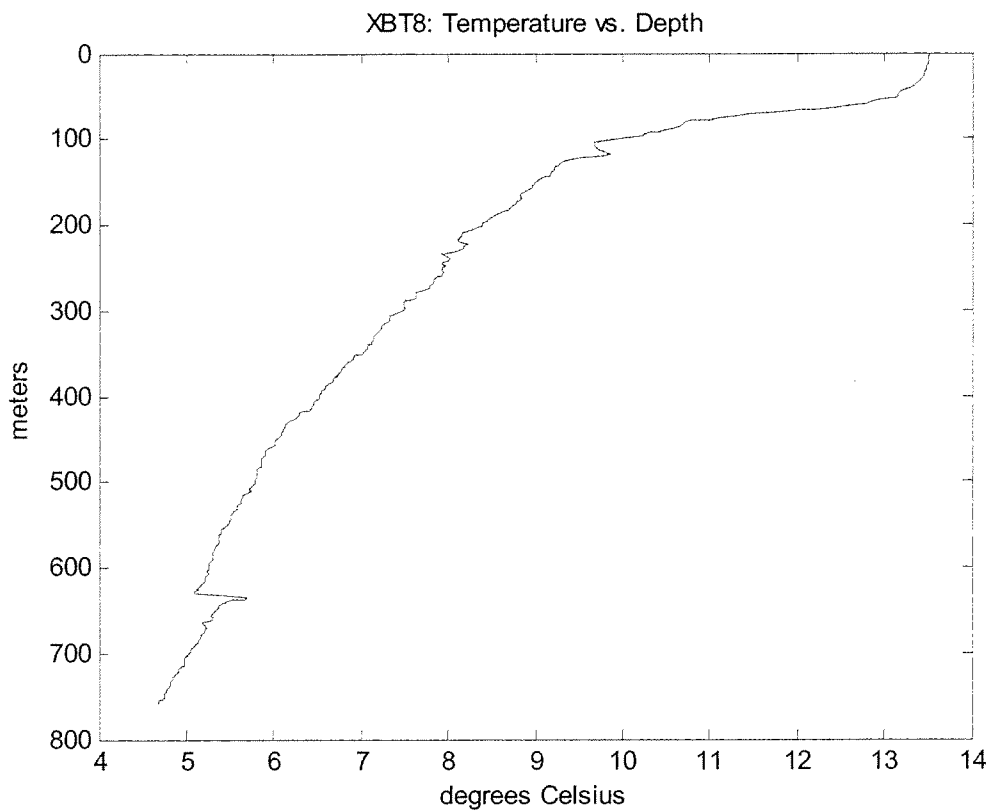### Location of CTD and XBT Temperature Profiles

Pair No.	XBT No.	XBT Latitude North	XBT Longitude West	CTD No.	CTD Latitude North	CTD Longitude West	Date
1	2	36.625	122.42	4	36.627	122.424	20 Jan 06
2	3	36.151	123.522	10	36.127	123.491	20 Jan 06
3	4	35.556	123.079	15	35.548	123.073	21 Jan 06
4	5	34.987	122.674	19	34.975	122.662	21 Jan 06
5	6	34.401	122.256	23	34.395	122.249	21 Jan 06
6	7	34.647	121.746	26	34.644	121.728	22 Jan 06
7	8	33.969	121.954	36	33.959	121.946	23 Jan 06
8	9	33.526	121.645	39	33.528	121.641	23 Jan 06
9	10	32.984	121.263	43	32.955	121.24	24 Jan 06
10	11	32.806	121.137	44	32.808	121.136	24 Jan 06
11	12	33.196	120.736	47	33.203	120.726	24 Jan 06
12	13	33.534	120.036	53	33.535	120.035	25 Jan 06
13	14	33.792	119.513	59	33.785	119.516	25 Jan 06

GDEM Site No.	GDEM Latitude North	GDEM Longitude West	Distance between XBT Location and GDEM Location (nm)
1	36.5	122.5	8.433
2	36.25	123.5	7.393
3	35.5	123	4.583
4	35	122.75	4.579
5	34.5	122.25	6.3
6	34.75	121.75	6.452
7	34	122	3.643
8	33.5	121.75	5.706
9	33	121.25	2.747
10	32.75	121.25	6.722
11	33.25	120.75	3.067
12	33.5	120	2.734
13	33.75	119.5	2.247

Appendix A: First table, position and date of CTD and XBT data used in this study. Second table, position of GDEM site used in this study, and the distance between that site and the XBT with the same number. CTD/XBT/GDEM numbers refer to the number in the cruise report; pair number refers to the pair numbering system used in this study for simplification and in the figures in further appendixes.
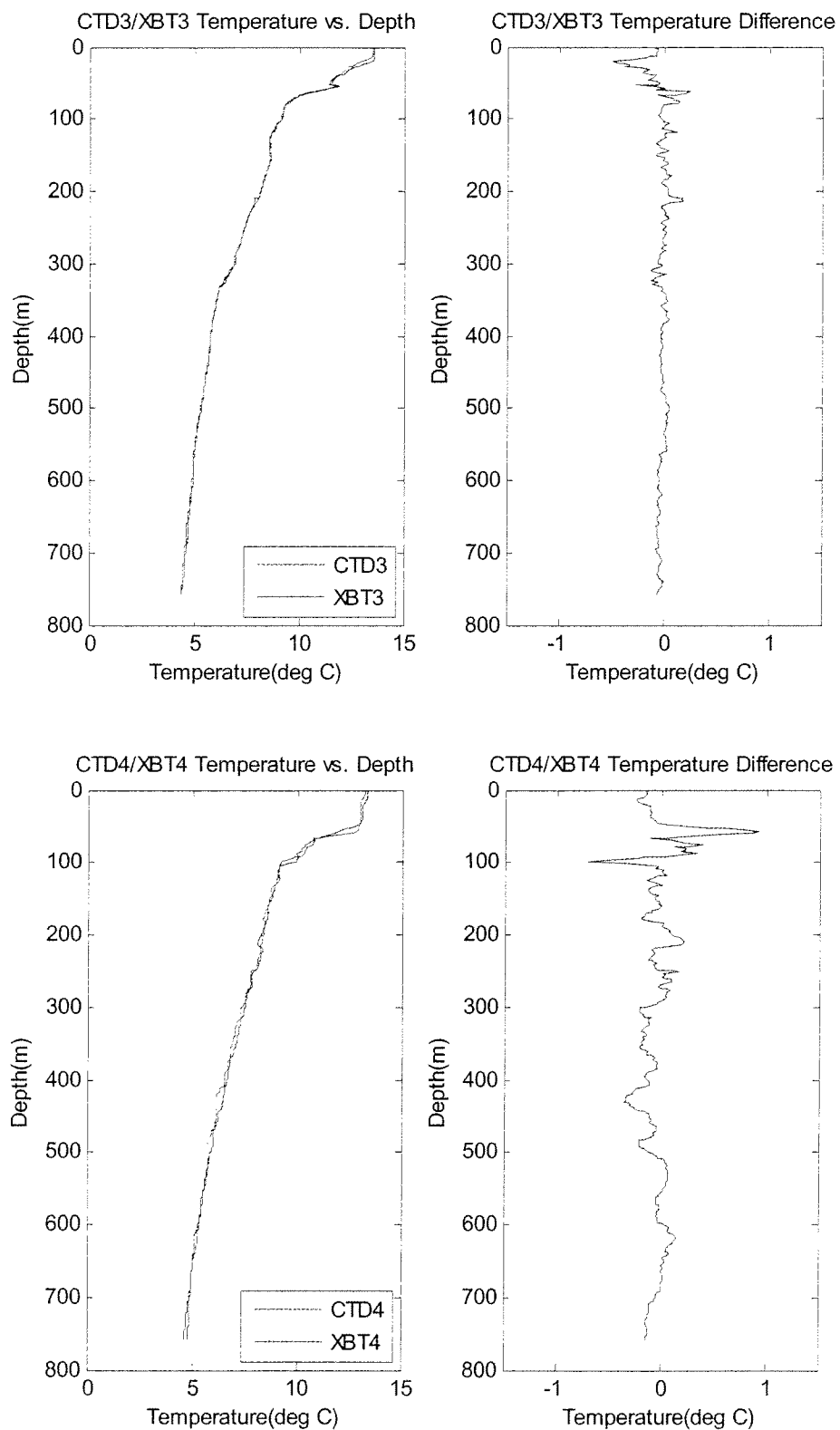
APPENDIX C
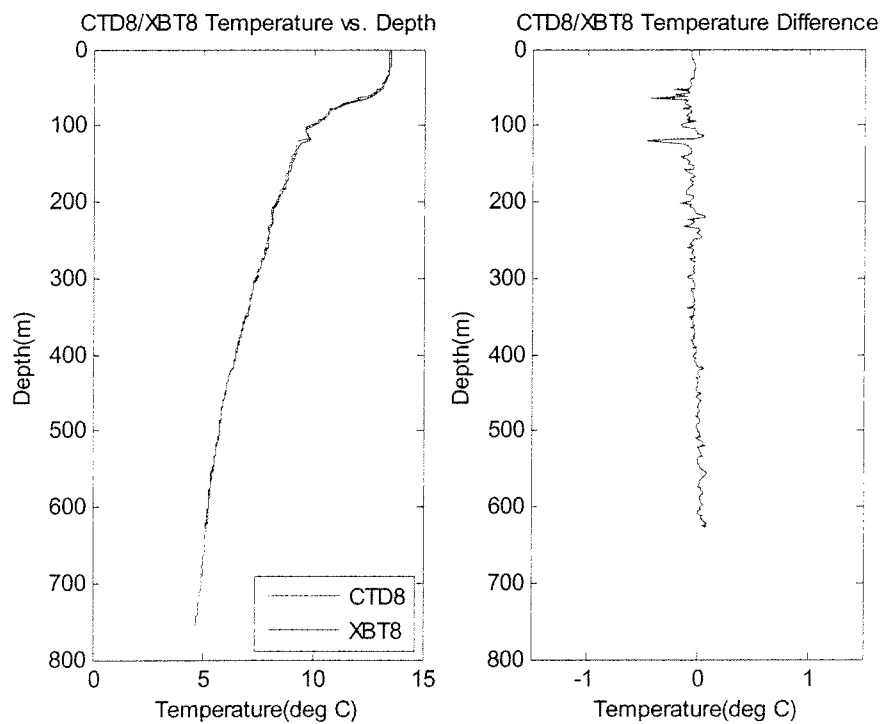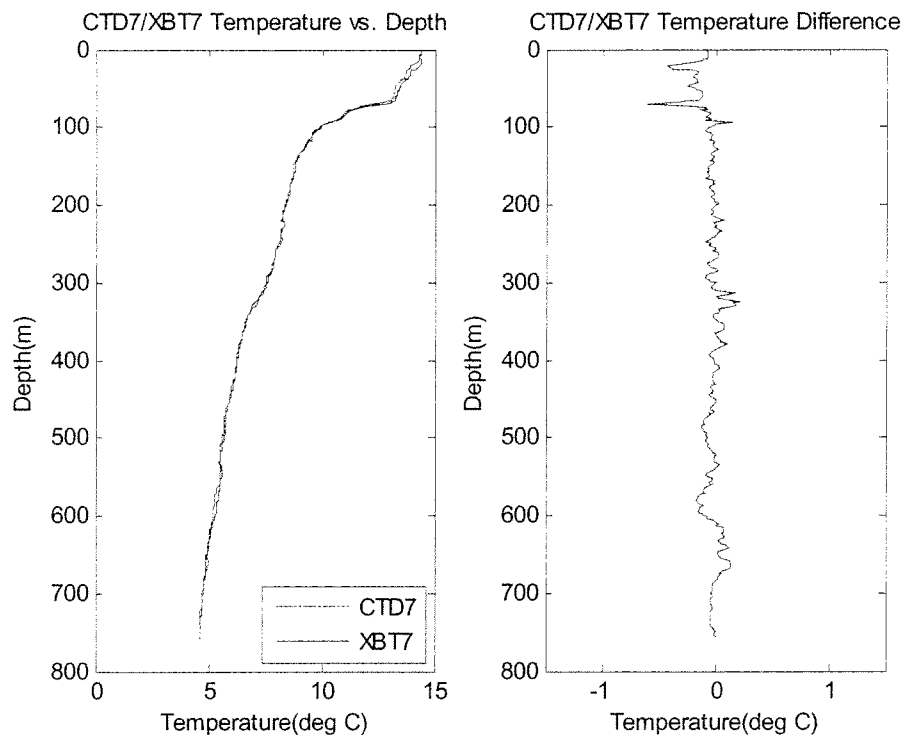### Bad Temperature Profile Plot

XBT8: Temperature vs. Depth

APPENDIX D
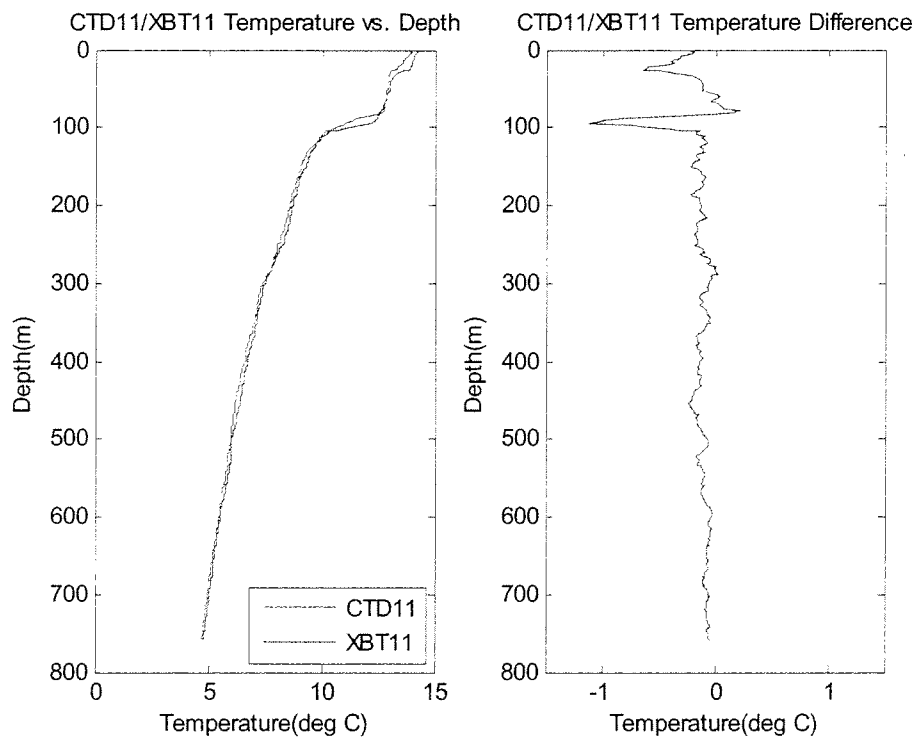## CTD and XBT Temperature Profiles and Difference Plots

CTD3/XBT3 Temperature vs. Depth

CTD3/XBT3 Temperature Difference

CTD4/XBT4 Temperature vs. Depth

CTD4/XBT4 Temperature Difference
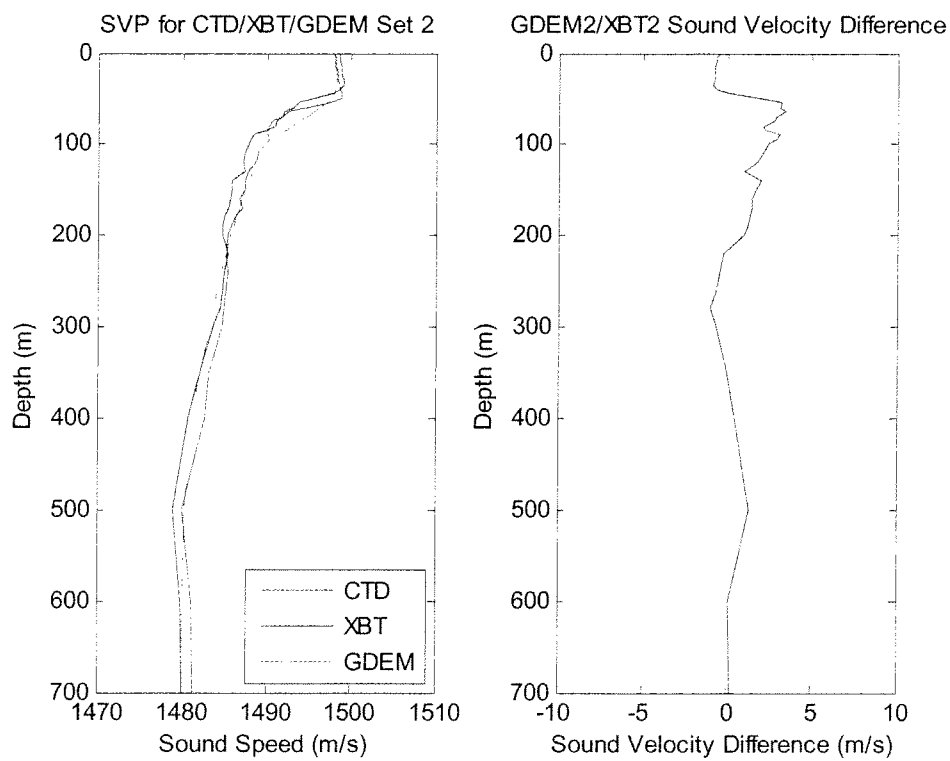
APPENDIX D
CTD and XBT Temperature Profiles and Difference Plots

CTD7/XBT7 Temperature vs. Depth

CTD7/XBT7 Temperature Difference

CTD8/XBT8 Temperature vs. Depth

CTD8/XBT8 Temperature Difference

APPENDIX D
CTD and XBT Temperature Profiles and Difference Plots

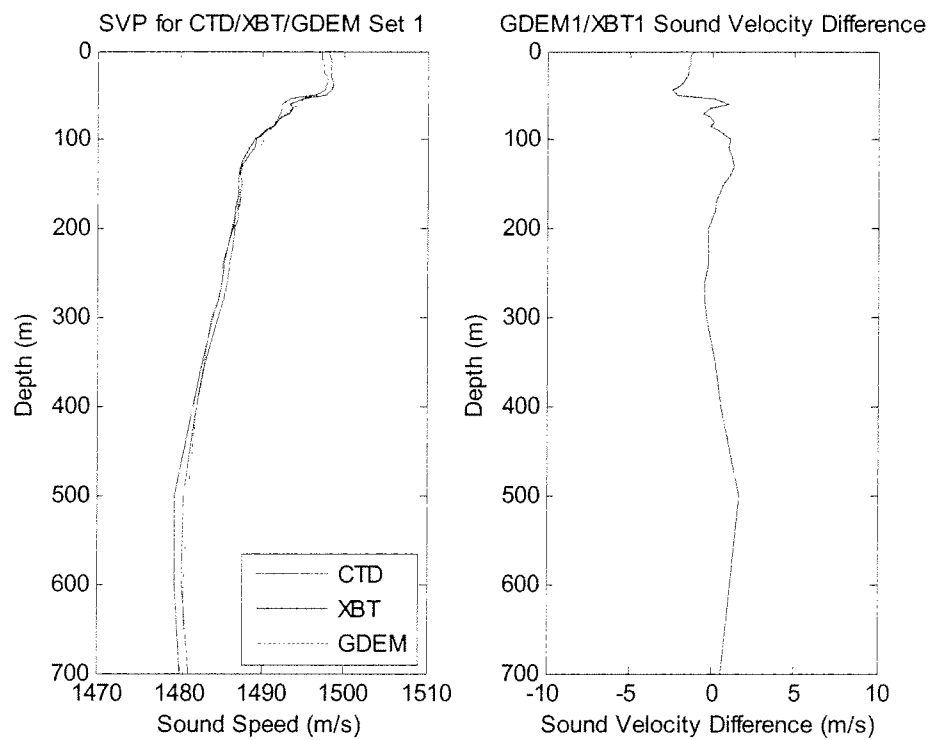CTD11/XBT11 Temperature vs. Depth

CTD11/XBT11 Temperature Difference

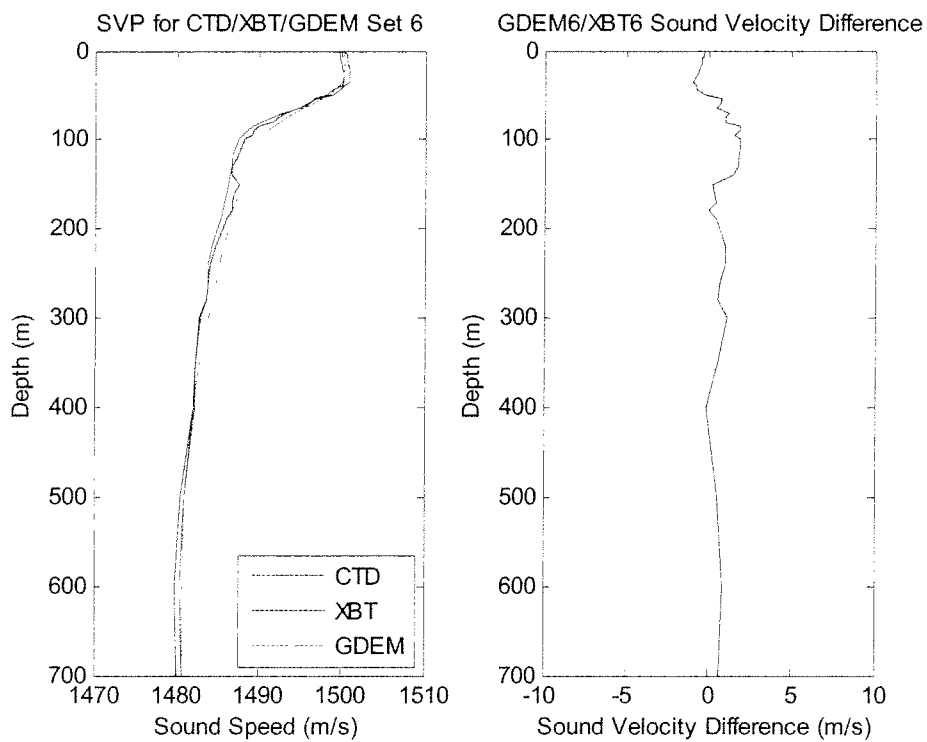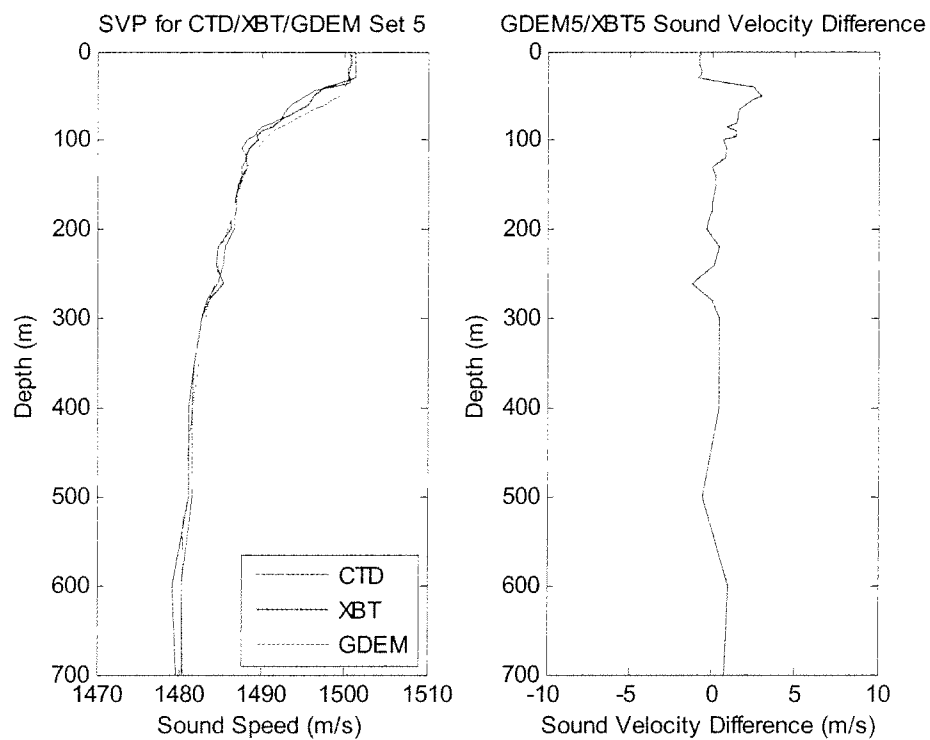CTD12/XBT12 Temperature vs. Depth

CTD12/XBT12 Temperature Difference

APPENDIX E
CTD and XBT Sound Velocity Profiles and Difference Plots

SVP for CTD/XBT/GDEM Set 1

GDEM1/XBT1 Sound Velocity Difference

SVP for CTD/XBT/GDEM Set 2

GDEM2/XBT2 Sound Velocity Difference

APPENDIX E
CTD and XBT Sound Velocity Profiles and Difference Plots

SVP for CTD/XBT/GDEM Set 5

GDEM5/XBT5 Sound Velocity Difference

SVP for CTD/XBT/GDEM Set 6

GDEM6/XBT6 Sound Velocity Difference

APPENDIX E
CTD and XBT Sound Velocity Profiles and Difference Plots

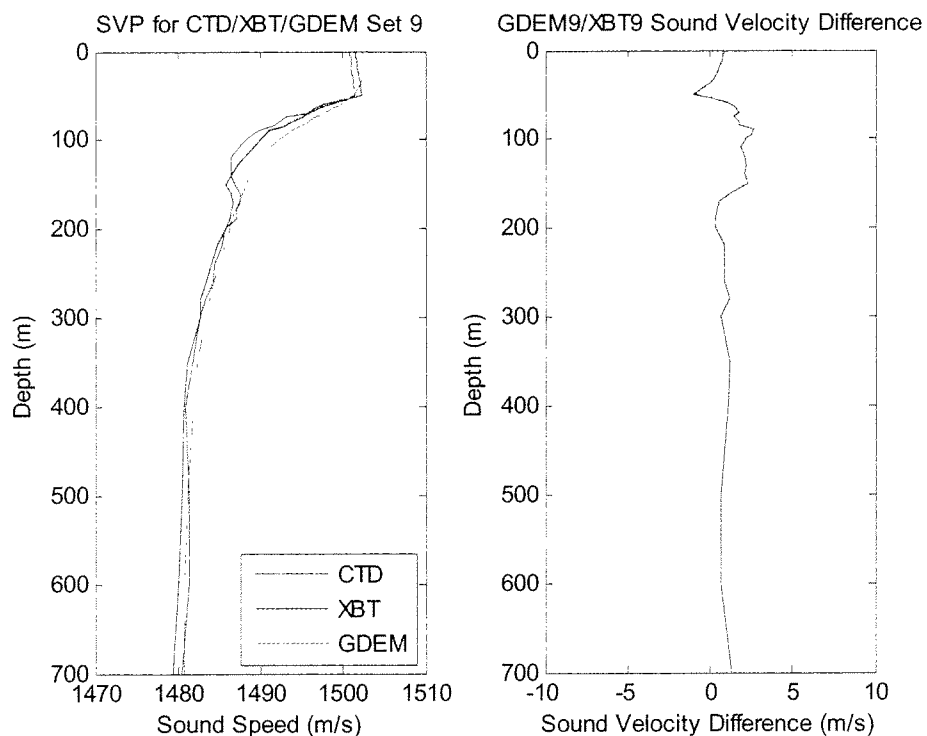SVP for CTD/XBT/GDEM Set 9

GDEM9/XBT9 Sound Velocity Difference

SVP for CTD/XBT/GDEM Set 10

GDEM10/XBT10 Sound Velocity Difference

CTD and XBT Sound Velocity Profiles and Difference Plots

SVP for CTD/XBT/GDEM Set 13

GDEM13/XBT13 Sound Velocity Difference

Composite GDEM-XBT Sound Velocity Difference and Standard Deviation